Webinar Transcript

Assessing the Relative Resilience Potential of Coral Reefs to Inform Management in the Northern Mariana Islands

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Ashley Isham: Good afternoon, or good morning from the U.S. Fish and Wildlife Service's National Conservation Training Center in Shepherdstown, West Virginia. My name is Ashley Fortune Isham. I would like to welcome you to our webinar series, held in partnership with the U.S. Geological Survey's National Climate Change and Wildlife Science Center in Reston, Virginia.

The NCCWSC climate change science and management webinar series highlights their sponsored science projects related to climate change impact and adaptation, and aims to increase awareness and inform participants like you about potential and predicted climate change impact on fish and on wildlife.

We appreciate you joining us today. I'd like to introduce Laurie Raymundo. She's at the University of Guam, and was one of the principal investigators with our speaker, Jeff Maynard. Laurie, welcome.

Laurie Raymundo: Good morning, Ashley.

Ashley: Good morning.

Laurie: [laughs] Yes, I have the honor of introducing a young man with whom I have enjoyed working, Dr. Jeff Maynard. He's an applied scientist. He works as a coral reef ecologist and he focuses on structured decision-making, risk analysis and climate change. He uses climate and ecological modeling to advance research into exploring and forecasting the impacts of climate change on coral reefs.

He also applies these advances with coral reef managers to help address the threats posed to reefs by climate change. He's especially interested in assessing the relative resilience potential of coral reefs and using the results of these assessments to target different types of management action.

This webinar is going to share the results of one of these ecological resilience assessments from a USGS PI CSC funded project that took place in the Commonwealth of the Northern Mariana Islands in the West Pacific last year. This is post bleaching. I'm very happy to welcome Jeff.

Ashley: Jeff.

Jeff Maynard: Good morning, afternoon, evening, and thank you, everyone, from me, for listening in. Laurie Raymundo, who you've just heard from, and I have had the great pleasure these last couple of years of co-leading a team of scientists and managers that have been working in CNMI to better understand spatial variation and resilience potential.

We have been applying what we've learned to the making of resilience-based management suggestions that are aiding our manager partners with planning. This is a highly collaborative project that was funded by a grant at the University of Guam's marine laboratory from the Pacific Islands Climate Science Center, which is based in Hawaii and led by Dr. David Helweg.

The PI CSC is one of the Climate Science Centers of the U.S. Geological Survey. We've enjoyed working with the PI CSC through the course of this project. PI CSC staff have helped with aspects of the presentation of our results and the project summaries we have prepared for the public.

As is usual to these large projects, many have contributed their time, expertise and ideas. I'm speaking today on behalf of everyone who has contributed, especially the main contributors listed and the project co-leaders, Laurie Raymundo of the University of Guam and Steven McKagan, who serves as the local NOAA Fisheries liaison in CNMI.

We'll cover 10 topics during today's talk. I'll provide the background and history of resilience assessments in reef areas, our study objectives, the steps of the resilience assessment process, highlights of our methods, how we analyzed our data, the ways we assessed anthropogenic stressors, the ways our results can inform management, and how we used connectivity to interpret our results.

I'll conclude by reviewing our main results, describing resources you can access and describing some of what we see as future directions for this research area. I want to first talk about how undertaking ecological resilience assessments got its start and how this idea and approach has evolved to what is being used and recommended today.

Much resilience theory, as it pertains to coral reefs, started in the wake of the global scale bleaching event of 1998, associated with the El Nino that occurred that year. Prior to the early to mid-1980s, bleaching tended to be rare and localized and corals generally recovered. There were even minor global scale events in 1987 and 1990.

The 1998 event, however, was something altogether different. Coral reefs in 60 countries were affected by bleaching, and up to 70 percent mortality was documented in severely affected areas. Overall, the widely reported statistic about the '98 coral bleaching event is that as much as 16 percent of the world's coral may have died that year. The 1998 event raised awareness of the implications of global warming and climate change, at least among the coral reef community.

The event also got people thinking since the impacts, so widespread, were clearly not spatially uniform. Jordan West of the US EPA and Rob Salm of the Nature Conservancy, who is shown here skin diving in the West Pacific, first proposed that spatial variation in factors that increase bleaching resistance and support recovery can be used as an assessment framework that can inform conservation.

We refer to these factors as resilience indicators. Areas with characteristics that reduce stress or confer resistance or support recovery processes may be more robust in the face of continuing climate change, and thus, are priority areas of target management actions to reduce stressors related to human activities.

The Nature Conservancy then included the concept of identifying areas with greater resilience potential, be it from resistance or recovery potential, in their conceptual resilience model, which was designed to assist with designing resilient networks of marine protected areas.

Sites with greater relative resilience potential are critical areas, and preferentially investing management effort in these areas is one of the guiding principles that can help ensure we support the natural resilience of coral reef systems. This is a critical point I want to highlight as I work through this simple summary of why ecological resilience assessments are useful.

The results can be used to target management actions that benefit site and system resilience, and thus, can help optimize application of our limited conservation and management resources. Importantly, up to 2009, none of these ideas had been formalized into guidance people could follow to undertake a resilience assessment. In 2009, scientists at the IUCN, TNC, and Great Barrier Reef Marine Park Authority published a guide for resilience assessment of coral reefs.

Features of the guidance within this document include that it was recommended that 61 indicators be assessed or measured, which meant implementing the framework was highly resource intensive and included many subjective assessments. For our work, the most recent and most important step in the evolution of the methods for resilience assessment in reef areas happened in 2012 at the Marine Conservation Congress in Vancouver.

A group of us designed a survey, 30 scientists and managers participated in, that examined what we considered to be the best subset of 30 of the previously proposed resilience indicators. Indicators were scored for perceived importance, scientific evidence and the feasibility of assessment and measurement. In the end, 11 indicators were recommended for resilience assessment.

These were in either the top 10 for perceived importance or for scientific evidence and were considered feasible to assess or measure. The recommended indicators are: resistant coral species, coral diversity, coral recruitment, coral disease, macro algae cover, herbivore biomass and temperature variability and the anthropogenic stressors, nutrients, sediments, visible human impacts and fishing pressure.

Our goal was to greatly reduce the number of indicators being assessed, as including weak indicators actually dilutes the importance of each indicator, and because evidence is increasing that, though complex, resilience processes in coral reefs are likely controlled by only a few factors.

We found no relationship between results using our new method and results using the methods proposed with the IUCN 2009, and found that using 11 indicators resulted in much greater separation among sites in assessed resilience. The research our team has undertaken in these last few years in CNMI represents the first field-based implementation of the ideas presented within the paper on prioritizing indicators that I just described.

Our collaborative work has three primary objectives - to assess the resilience potential of areas where management activities have already been implemented, to identify priority conservation areas and better understand the primary drivers of resilience potential at the island, and CNMI wide scale. We also had a secondary objective.

This was to support the coral reef conservation community by developing a detailed, adaptable process that guides the implementation of ecological resilience assessments. There are six steps in the process we used. These are: deciding whether to undertake an assessment, selecting indicators, collecting and compiling the data, analyzing the data, then identifying sites that warrant management attention and presenting and communicating the results.

We're going to review these steps during this presentation, and I've listed the relevant steps on some of the slides. I'll re-review these once I've shared all the results, as I think it's easier to understand all the steps once you've seen our example. I'll start describing our research by providing some highlights of the methods we used. We measured or assessed all 11 of the indicators recommended within the McClanahan et al. 2012 review.

I want to be really clear here that the stressors related to human activity, listed at the end, are considered resilience indicators within the list of 11 recommended in the review. However, these challenge resilience, so are unlike the others, which are all indicators of resilience processes. Keep in mind through the coming slides that the anthropogenic stressors are assessed separately in our assessment. They're not included in the assessment of relative resilience potential.

I'll review how they fit into our decision support framework a bit later in the presentation. Moving on to the indicators included in our resilience assessment and our field work. For the coral community, 12 to 16 quarter meter quadrants were used and all corals were identified to species, and the longest and perpendicular diameter were both estimated. In all, approximately 160 coral species were identified during our surveys.

Stationary point counts were used to assess the fish community. One of our project co-leaders, Steve McKagan, conducted a minimum of nine three minute long stationary point counts, identified all fish to species and estimated their lengths. In all, Steve estimated the lengths of tens of thousands of reef fish and identified 250 species.

You'll see, we put a small step two up, top right of this slide, as this is the step when indicators are selected and methods decided on. We surveyed 78 sites along the 30 foot contour of the four reefs of four islands of the CNMI, including Saipan, Tinian, Guguan and Rota. This map of our survey sites in Saipan shows that we had good spatial coverage around these islands, with our sites roughly a mile apart all the way around the island.

This slide reviews the six indicators that were actually included in our assessment. Aside from the coral and fish communities, which I described on the previous slide, warm season temperature variability is also included. As sites where warm season temperatures are more variable, they'd be better acclimated to the temperature extremes that cause coral bleaching.

The units are listed here, and as will be obvious to everyone, the units for all these indicators are necessarily very different. This is a key point as it speaks to the first required specimen data analysis, which I'll describe in an upcoming data analysis slide. One point, though, about our resilience indicators. We consulted colleagues working within the Nature Conservancy and NOAA's Coral Reef Ecosystems Division in developing our herbivore biomass metric.

Our method is inclusive of three herbivore functional groups. We calculated that average biomass in kilograms per hectare of these three groups. Consequently, our herbivore biomass metric is inclusive of herbivore diversity, which much recent research suggests is just as important as herbivore biomass. This means that our average biomass values are not directly comparable with total herbivore biomass values from elsewhere.

Now, over just a couple of minutes, I'll share a little of what represented many hundreds of person hours for our team. The reefs in CNMI are really, really beautiful. There are well over 400 reef fish species in CNMI, and at least 200 coral species, meaning CNMI definitely has among the greatest reef biodiversity among US coral reef locations. We learned, remarkably, the waters in CNMI are very clear.

We set out three 50 meter transects, and people that were serving on snorkel safety support could frequently see our entire dive team in transects across a 100 plus meters of reefs. Here is Steve McKagan undertaking a fish species census to end his dive. He's diving in the coral gardens near Rota, which is in one of the established marine protected areas in CNMI. These photos will give you a bit of virtual tour.

Another of our co-leaders, Laurie Raymundo, is shown here assessing the coral community and coral disease prevalence at a site near Tinian Island. Steven Johnson is a reef ecologist with the marine monitoring team in CNMI. He's one of our two coral biologists and is a new Masters of Science student at the University of Guam's marine laboratory. Trust me, I would have liked to have shown him wearing a little more than he is here, but he only ever dives in board shorts.

Here's Lyza Johnston. Liza is the science and team lead for the CNMI marine monitoring team. She is assessing the coral community at Bird Island, which is in northeast Saipan, and is another of the established marine protected areas in CNMI. Here are a few photos from other sites we surveyed to help you visualize what the coral reefs in CNMI are like.

I'll now talk everyone through the basics of step four - analyzing the data you collect and compile the resilient indicators. I'm calling this a look under the hood. You can see all of you in the audience depicted there in the top right. I thought if I showed a side-on view of this bloke working on a car, it would help to get your attention for the only slide I'll share that has a pretty detailed description of how the math for these analyses works.

I mentioned before that each of the resilience indicators that we include in our assessment has different units. This means that all of the indicators have different scales. The data have to be normalized and converted to a unidirectional scale prior to calculating a composite score for resilience potential. To normalize the data, all values for each indicator are divided by the maximum value.

This expresses all values as a decimal percentage of the site with the maximum value and ensures all indicators have a scale ranging from zero to one. The scale is inverted for macro algae covers, such that a high score always means higher relative resilience potential, which is why I call it a unidirectional scale. High score's always a good score. These normalized scores are then scaled or weighted.

Part of Table Two from McClanahan et al. 2012, is re-shown here. We compared the perceived importance scores by dividing these scores by the lowest important score for our indicators. This results in a multiplying factor you can see it on the right there, ranging from 1.36 to one, up top. The normalized scores for the indicators are weighted using these multiplying factors because we intuitively know that some of the indicators are more important than others.

The normalized scores are multiplied by the scaling factors we calculated. These converted scores are then averaged to produce the raw score for resilience potential. These values are then re-normalized, which expresses resilience potential for each site as a decimal percentage of the site with the maximum score. We call it relative resilience potential.

We then rank the sites from high to lowest score and use four relative classes based on where the final score fit into the distribution of scores. Sites with low relative resilience had scores less than the average minus one standard deviation. Sites with high scores had scores greater than the average plus one standard deviation.

On this map, we show the results for our analysis that compared all sites against all other sites. On the top right, you can see the distribution of resilience scores with the average near 0.8. The assessment results suggest the resilience of 17 of the sites is distinctly different and either greater or lower than the distribution defined by the average plus and minus one standard deviation.

Seven of the sites have high relative resilience potential, and 10 have low relative resilience. 37 of the sites have medium-high, and 24 of the sites have medium-low relative resilience potential. All but one of the established MPAs has high or medium-high relative resilience.

We had no preconceived notions as to where exactly the sites with highest and lowest relative resilience potential would be in CNMI, but suspected the sites most remote and least exposed to anthropogenic stressors would be among those with the highest resilience scores. We found the exact opposite to be the case. The majority of the high resilience locations among the surveyed islands are in Saipan, where greater than 90 percent of the 50,000 people residing in CNMI live.

There are no high resilience sites in Rota, which is 50 kilometers south of Tinian and Aguijan, and roughly 50 kilometers north of Guam. That island has only 2,000 residents. Indeed, seven of the ten low resilience sites are in Rota. Our connectivity simulations help to explain this result, and I'll review those simulations in upcoming slides.

Hopefully it's not too bad a memory, but I want to quickly show the looks under the hood and data analysis we'll have to distribute. This is just so that I can share that those steps I described can be undertaken for multiple spatial scales. On the slide I just presented, I mentioned that all of our survey sites were compared against all other survey sites.

For the analysis shown on this slide, sites were only compared against sites surveyed on the same island, with Tinian and Aguijan combined. Conducted two analyses so that our results could inform decision-making, both at the region wide and island level scale. We found that there are at least two locations with low relative resilience potential and two sites with high relative resilience potential at each island.

Generally, sites on more exposed sides of the island, east for Saipan and Tinian, and south for Rota have higher relative resilience potential. Understanding which variables most influenced differences in resilience potential is another valuable product of resilience investment.

This is because the indicators most influencing rankings are the most important to include in monitoring programs, and they reveal the types of management actions that would benefit the greatest number of sites. We used two different analyses to examine which of the indicators are most driving differences in resilience potential among our survey sites, which was our project objective too.

The scaling factors we used are pretty small. They're shown again here on the top right. Resulting in increases in the scores of greater than ten percent for only two of our indicators. Consequently, variation in the scores for the variables is indicative of which indicators are most driving rankings. Indicators with greater variability are most distinguishing sites from one another.

You can clearly see for the inter-island and all three intra-island analyses that coral recruitment and herbivore biomass are the most variable indicators and have the greatest range in value. We also used a canonical analysis of principle coordinates, which is a type of ordination analysis conducted in collaboration with our group by Gareth Williams, who works at Scripps Institution of Oceanography in San Diego.

You can see that the relative classes we set are very different from one another, and clearly line up along the horizontal axis. The length of the line for each of the variables is indicative of the importance of the variable in distinguishing sites. Herbivore biomass, coral diversity, coral recruitment and macro algae cover are most driving differences among sites.

We conducted the same analysis for the three islands and island groups. As is shown here for Rota, herbivore biomass and coral recruitment are driving differences in resilience potential as assessed here and this was the result for all of the surveyed islands. I mentioned earlier that the anthropogenic stressors were assessed separately to the resilience indicators.

Anthropogenic physical impacts, such as from anchoring, were excluded as we observed almost none of these kinds of impacts during our surveys. However, we assessed land-based sources of pollution, which is inclusive of both nutrients and sediments as well as fishing access using GIS software and existing spatial data layers.

For LBSP, we used land use spatial data layers from the forest service, and worked out which drainages affected each of the sites that we surveyed. Our LBSP metric included the proportion of the relevant drainages made up by urban and cleared land and the local human population density. The color scheme is the same here as is shown on the other maps in that green is good. So green scores would be low here. We're still using the relative scale.

There were no sites with LBSP values in CNMI lower than the average minus one standard deviation. You can see, though, that there are sites with above average LBSP values and even sites with values greater than the average plus one standard deviation. LBSP values are, of course, highest near human populations and near cleared lands.

For fishing access, our assumptions are that access to the fishery in these islands is primarily determined by the average wave height at a site, the distance between that site and an access point, such as a marina or boat ramp, and the human population density near the closest access point. There's good evidence that this is the case, given the exposed sides of these islands are difficult to impossible for small craft to access for much of the year.

The wave symbols show prevailing wind exposure at the islands we surveyed. You can see access is low in these locations, which we assumed to be of benefit to the coral reef fish community. i.e., fishing pressure is probably lower in locations with high wave exposure and greater in locations with low wave exposure. We've now reviewed the first four of the six steps I described, and some of the six, given I've shown how we presented our main results in maps and tables.

Step five is as or even more important than the others. It's where you could say "the rubber hits the road." This is where we maximize the value of the assessments and analyses for informing management decision-making. We set up a total of six custom queries of our data. And set criteria for these queries given there are different reasons sites may warrant management attention and actions to support resilience processes.

Our queries identified targets for conservation, LBSP reduction, fishery regulations and enforcement, bleaching monitoring and supporting recovery, reef restoration and coral translocation, and tourism outreach and stewardship. Our first three queries are based on targeting actions to sites with greater relative resilience potential.

This thinking is based on results presented within a "Conservation Biology" paper written in 2008 by Ed Game, who now works with TNC, and a few of his colleagues. The long and short of the findings from the modeling is that we should protect strong or high resilience sites if we are expecting sites to spend most of their time in a degraded state.

The benefits of many types of management actions take a long time to manifest and disturbance frequencies are expected to increase in the coming decades as our climate changes. For these reasons, high resilience sites have greater conservation priorities. You may remember that I mentioned on one of the introductory slides that high resilience sites are among the critical areas we need to manage to support site and system resilience.

A whole presentation could be prepared to explain that line of thinking. I'm sorry I had to review that so quickly for this webinar. I'll bring this up again really briefly when I review vulnerability assessments on one of the future direction slides. I'll show two examples of the results of the queries I just described. We identified high and low resilience sites that are currently outside established no-take MPAs.

As I was saying, the high resilience sites that aren't currently being protected can be considered conservation priorities. New MPAs or temporary closures or similar are not planned for CNMI right now, importantly. There are a range of other management initiatives that can be considered, though, including other types of fishing regulations along with increased enforcement and debris removal.

This example is shared because many managers in coral reef areas will want to undertake an ecological resilience assessment to identify high resilience conservation priority sites. This is how we went about that. You can see the results, that there are high resilience sites not currently protected or rather not currently within the MPA-type of protection in both Saipan and Tinian.

With this query, we show the locations that have high or medium-high relative resilience and above average scores for land based sources of pollution. These are targets for LBSP reduction. 13 of the 78 sites meet the criteria set for this query. This summary graphic has the first letter of the query name within purple circles for all of the sites to which the criteria for at least one of the queries applied.

In total, 55 of the 78 survey sites meet at least one of the six sets of query criteria. I want to make two important closing points about the queries we used to identify targets for different types of management actions. Firstly, the list of queries we set is not exhaustive of all the possible options. This is one of many reasons we always stress that the process we used in CNMI can be replicated or adapted.

There are likely to be other kinds of queries that will make sense in other areas depending on the local context and the type of stressors related to human activity that are most likely to be challenging the resilience of local reefs. Secondly, we know that none of the management action options I've just described are new. The innovation is in using resilience explicitly as an information layer such that actions are targeted to maximize site and system resilience.

Within our project, we also examined connectivity at the island scale. This part of the broader study involved collaboration with Matt Kendall, who works with NOAA's bio-geography branch, and happened to be concurrently leading a project examining connectivity in CNMI while we were conducting our resilience assessments.

Understanding connectivity, even at the whole-island scale, can help us better understand the resilience assessment results and decide where to implement management actions. This second point has two parts. We can identify where actions are required to maintain larvae supply, and where actions may be ineffective, due to the larvae supply being really limited.

The question we wanted to answer was, "What is the relative extent to which each of our survey islands is a larvae source and destination?" All I'm going to share about the methods for the connectivity simulations is that they're cool and really complicated. As you can see from this animation on the right, which shows a 4D hybrid coordinate ocean model with a one day time-step, which was used to examine connectivity by resolving island scale current patterns.

We used two simulations. One that assumed larvae had no swimming ability, which is the case for coral larvae. And another that assumed larvae could swim with sensory capacity, which is often the case with reef fish larvae. We also included four pelagic larval durations to capture the range of days coral and fish larvae spend in the pelagic environment before settling.

Our results took the form of eight matrices set out as you see here, with sources as columns and destinations as rows. Numbers in the table cells are virtual larvae. And we examined connectivity among our survey islands within the CNMI portion of the Marianas chain, Guam and other archipelagos.

Here's the really simple summary. Considering both simulations and all four of the pelagic larval durations we used, Saipan is roughly twice the source as Tinian and Aguijan is and ten times the source that Rota is. Saipan and Tinian and Aguijan are comparable destinations and roughly twice the destination that Rota is. Here's what those results mean for the two reasons I described that summarize our interest in the connectivity information.

Firstly, the lower connectivity between Rota and the other islands may be why seven of the ten sites with low relative resilience potential are in Rota. Secondly, management actions to reduce stress and support resilience in Saipan and Tinian/Aguijan can help to maintain larvae supply. Also, actions to support resilience in Rota may be insufficient to support recovery there, given the limited supply of larvae.

We've covered a fair bit of ground, so I want to offer four highlights of our results that work as take-home messages. The first is that resilience potential varied greatly within and among islands for our analyses, and some sites have high and some have low relative resilience potential. Secondly, herbivore biomass and coral recruitment are key drivers in CNMI of differences in relative resilience potential as assessed here.

The majority of sites were identified as warranting management attention for at least one reason we can relate to an action that will support resilience. Lastly, connectivity information really helps explain assessment results and prioritize from among the sites that warrant management attention.

Here are our six steps again to review. First, was deciding whether to undertake an assessment. The second was selecting indicators. Third was collecting and compiling data. The fourth is analyzing the data. The fifth, identifying sites that warrant management attention. The sixth, presenting and communicating the results. I want to emphasize to you that our team considers scientist and manager collaboration to be essential for all of these steps.

I actually had to remake this graphic because the first only had a sign on one side, which is actually indicative of the problem rather than the solution. The solutions we need and the building of stronger bridges between science and management requires scientists make suggestions to managers and vice-versa. Our team believes our work to be a great example in the realm of operationalizing resilience, of scientists and managers collaborating.

More collaboration like this are required both to undertake work like what we described, and so that the work can evolve and be refined and improved. As detailed as this presentation has been, this is really a highlight-like summary of what has been a really large body of work that has produced more results and local management suggestions than can be summarized here. The main aspect of our work and some important theoretical background hasn't been covered.

However, we have produced a range of resources that share our process and our project results so that people can learn more about our work. These include our 2012 project report available on a NOAA CORIS website. A how-to guide for undertaking resilience assessment is available on the TNC's reef resilience web page. Summaries of our guidance undertaking resilience assessments, which can also be found on TNC's reef resilience web page.

A workshop report on resilience-based management from a resilience-based management workshop held in Honolulu late last year. Our USGS Pacific Islands Climate Science Center project report, which is available on a USGS web page that describes our project. And an 84-page site summary appendix we are currently finishing to share results and management suggestion for each of the sites we surveyed.

Lastly, we just submitted a manuscript for review that will be published open access later this year. All of these materials are either publicly accessible now or available upon request by sending me or one of the other project leaders an email. There are two different future directions for the applied research presented here that I want to quickly review before I conclude.

Firstly, I want to make clear that the relative importance of resilience indicators will very spatially, especially among reef regions. For this reason, those interested in undertaking an assessment can start with recommended lists, and then include and exclude indicators as is appropriate for local context. We're going to need to develop recommended lists for the indicators for different reef regions. Those aren't available now.

For example, we know the drivers of resilience processes are different in the Caribbean than they are in the Pacific. This is visually exemplified here using two photos from sites that were rated as having the greatest relative resilience potential from an assessment undertaking in the Cayman Islands in the Caribbean and for our study in CNMI.

Secondly, we can undertake vulnerability assessments that combine resilience assessments with remote sensing and climate model based maps and projections of spatial variations and exposure to disturbances. In the IPCC’s framework for assessing vulnerability, exposure and sensitivity combined to produce potential impact which is moderated by adaptive capacity to yield vulnerability.

The sensitivity and adaptive capacity terms can be seen as resilience, so by combining resilience assessments with exposure information, we can both assess vulnerability and target actions to the site with the lowest vulnerability. These are the high resilient sites with lower projected exposure. For example, we recently produced downscaled projections of coral bleaching conditions for the Caribbean.

These projections are 4-km resolution and we identified countries where the variation in the projected timing of the onset of annual severe bleaching conditions is greater than 10 years. In doing so, we're identifying locations that maybe temporarily refugia. It'll be interesting in coming years to identify locations that meet that criteria and have greater relative resilience.

I'm just sort of scratching the surface of the kind of mapping our and other teams are doing in this working area, but, hopefully, you can see the potential. This and next year, Laurie Raymundo and I will lead another PI CSC project related to this modeling capability in collaboration with Ruben van Hooidonk. We will be producing downscale climate model projections from Micronesia.

We'll be combining resilience assessment results with our downscale projections to collaboratively develop sustainability forecast with managers and reef stakeholders. I'm going to leave this slide up so that the recording shows the details of references cited in the presentation.

[silence]

Jeff: I want to conclude the way I started, to reiterate that this project includes numerous contributors and has been made possible by funding provided by the USGS Pacific Island Climate Science Center along with grants to the project leaders from the other agencies listed here.

Contact details of the project leaders are on the bottom right. While I'm likely to have enough time for all of the questions people have, I really encourage people to get in touch via email to provide comments or ask questions, even to set up the time to discuss the project results or assessment process. Thanks once again for everyone's attention and for your interest in our project.

Ashley: Excellent. Thank you very much, Jeff. All right. I see that some are coming in. I'd like to take the first question. It's going to come from Carl. It says, "Is there any concern relating to sea currents and ecological resiliencies of coral reefs?"

Jeff: I see that, I guess in the first instance, as a really broad question. If you write me, then we can put you in touch with Matt Kendall who was really the specialist that worked with us that did all the connectivity simulation that we summarized in the matrices that we used to make our various management recommendations and to interpret our results.

The short answer, sort of broadly is that, yes, certainly there's uncertainty in that kind of modeling when we think about the future and how future changes in regional and global climate may affect currents because there's future uncertainty in that modeling. For us, it's still uncertain at the island scale. We saw it as being the best available information on a really important aspect of resilience at the best possible scale. Rather than ignore it, we build it in to the extent possible.

I think it's a strength of what we've been able to do because it would have been confusing, I think, to a lot of people that worked in CNMI with us that suspected even more strongly than we did that the sites in Rota that are very far from where most of the people live didn't fare better in the assessment.

Having the connectivity results helps us to explain that and, as you saw, really create a lens for us for how we can prioritize management actions among the island. There's definitely concerns about the uncertainty related to the work, but that's the best available information at the best available scale. As it's improved and refined, it can be continually included in these kinds of assessments and in future assessments. Hopefully, that touches on what you're asking.

[silence]

Ashley: Thank you. The next question is from Bob Glazer. Hi, Bob. "Jeff, I'm particularly intrigue by the connectivity issues. You presented it well with respect to resilience and biodiversity conservation. I'm wondering if you would care to speculate on what it means for regulation, with respect to fisheries management and fisheries sustainability."

Jeff: Two questions on connectivity which really wasn't the part I was leading. This is particularly a tough one, so I don't want to necessarily just table it because I feel that question for the role that we had in this work needs to be answered by local managers that were working with us in CNMI.

I can say though that the report that Matt Kendall and his colleagues produced is becoming available around the same time that we were developing this webinar. It's only in this last couple of months that people in Guam, where they're having Coral Reef Symposium this week actually, and in CNMI became exposed to it.

It's definitely raising a lot of eyebrows, perking a lot of ears or whatever expression you want to use. They're looking into it. I think it will be built in the future fisheries management. How exactly, you'll need to follow up with us on a bit later. We could put you in contact with the managers that really are making those decisions.

Ashley: I'm not seeing any more hands or questions coming into the chat box. Holly, are you still on? Did you want to make any closing remarks?

Holly: I am on. This is Holly at the USGS and NCCWSC. We just like to say thank you to Jeff. That was excellent. It's always good to see what's going on out in the field. Thanks again.

Ashley: Thanks, Holly. I saw Dave on who was key in this as well in supporting it. I just want to give him the opportunity to make any remarks as well.

Dave: I'm very appreciative of both Laurie and Jeff and the team's hard work both in the field, the blitz they did on data collection, and they're windows to good weather, all of this is very sophisticated analytic work that went into this presentation. Thank you also to Ashley and Holly for helping us set this up. I hope this is just the first of a long series of collaborations between the Climate Science Center and the teams out in the Western Pacific.

Ashley: Thanks, Dave. All right. Well, I'd like to say one more time. Thank you very much, Jeff. That was a wonderful presentation.

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